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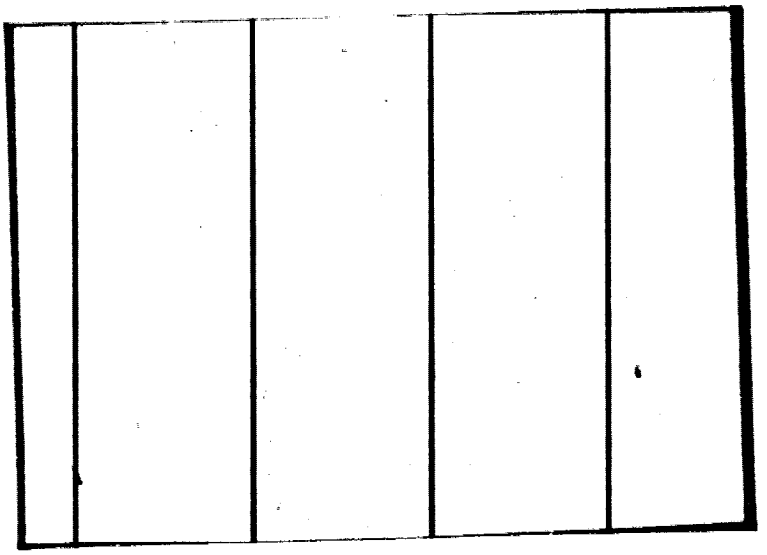

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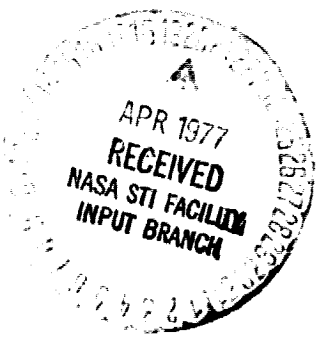

GROUND-BASED DOSIMETRY SUPPORT FOR EXPERIMENT AR002*

by

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Technical Report No. 43

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*Work funded by NASA-Johnson Space Center under Contract NAS9-14396

ABSTRACT

This report covers two biological experiments conducted at the Lawrence Berkeley Laboratory's 184-inch cyclotron and Bevalac Bio-Medical Facility for Drs. M. Brower and T. Rogers. The first experiment was performed in June of 1975 when Actinomyces levoris colonies were exposed to alpha particles at the 184-inch cyclotron. The second experiment was performed in February of 1976 when Streptomyces levoris colonies were exposed to Ne^{20} ions at the Bevalac Bio-Medical Facility.

A description is given of the experimental conditions for each experiment along with tables listing the doses delivered to the colonies. The doses for the Actinomyces levoris exposures came from calibrations made by the cyclotron operators, while the doses for the Streptomyces levoris exposures came in part from the Bio-Medical cave calibrations and also in part from our own calculations.

I. Actinomyces levoris

On June 4, 1975, twenty Petri dishes containing Actinomyces levoris colonies were exposed to 233 MeV/nuc alpha particles at the 184-inch Berkeley cyclotron. Five exposures of four Petri dishes each were made at doses of 280 rads, 28 rads, 2.8 rads, 0.32 rads, and 0.025 rads, and four additional samples were used as controls. Figure 1 depicts the orientation of each group in the beam and Table 1 shows the exposures delivered to each sample; since the alpha beam was very energetic, the dose is fairly constant longitudinally in the region of interest, so that each colony in a group received essentially the same dose.

In preparation for this run, 150 experimental samples were innoculated on May 19, 1975, and subsequently placed in a fume hood where they were exposed to normal room light and room temperature. On May 23, 1975, the samples were moved to an incubator in which they were continuously illuminated by a 10-watt light bulb at an average distance of about 20 cm; the temperature in the incubator was normally 20°C, although for one day it reached 33°C.

On June 4, twenty-four of the 150 samples were selected for exposure and control. These samples, numbered C1 through C24, were of two types:

1) Distinct, thin, but poorly formed rings
   (even numbers C2, C4, etc.)
2) Thick, almost overlapping; but well formed rings
   (odd numbers C1, C3, etc.)

Samples C11, C12, C23, and C24 were used as controls.

These twenty-four samples were photographed before exposure and again about four hours after exposure (four, 300-watt light bulbs illuminated each Petri dish for about one second during photographing--sample C1 was initially photographed three times). The colonies were removed from the incubator at 13:00 hours PST, transported to the cyclotron, and then exposed at about 15:20

hours PST. After the second photographing, the colonies were immediately shipped to the NASA-Johnson Space Center.

II. Streptomyces levoris

On February 11 and 12, 1976, a series of exposures were made at the Berkeley Bevalac Bio-Medical Facility; separate colonies of Streptomyces levoris received exposures ranging from 125 rads to 12,500 rads (entrance doses) and to approximately four times these values at the Bragg peak. Five Lexan Petri dishes, each containing two Streptomyces levoris spore colonies, were placed in the Ne^{20} beam at one time; the Bio-Medical cave operators focused and collimated the beam so that only five of the ten colonies (one in each Petri dish) were exposed at a time--the beam spot was approximately one centimeter in diameter. The approximate depth-dose curve (normalized to 100 rads entrance dose) is shown in Figure 2; the positions of the colonies are also shown. The estimated doses delivered to the more exposed colonies can be calculated by dividing the entrance doses (Table 2) by 100 and then multiplying by the dose read from Figure 2. The depth-dose curve was calculated by numerically integrating

$$\phi = 1.602 \times 10^{-8} \int_0^{LET_{max}} LET \left(\frac{dN}{dLET} \right) dLET$$

$\phi \equiv$ Dose in rads

When one is far enough away from the Bragg peak a power function approximation for the dose is quite adequate; this power function approximation was used in the appropriate region.

In the course of the experiment, no actual measurement was made of the straggling in the beam. In order to compute the dose in the Bragg peak region, this parameter must be known. The sigma (which is directly related to the straggling) used for this dose calculation was actually an average value computed from three other 400 MeV/nuc Ne^{20} runs where the spread in the beam had

actually been measured. Since the experimental conditions (i.e., the energy, the water column thickness, and the final residual range) for this experiment were very similar to the other three neon runs, the average value, σ_{ave} = 0.0601 cm of water, used is believed to be a valid approximation. The position of the Bragg peak was determined by the Bio-Med cave operators and the Bragg peak in Fig. 2 was adjusted to match this value.

The arrangement of the Petri dishes during exposure is shown in Fig. 3; the six 10 mil by 9 cm diameter red Daicell cellulose nitrate SSTDs (solid state track detectors) are also shown. An attempt was made to do a fluence calibration using the cellulose nitrate detectors, but it soon became apparent that this would be impossible for several reasons:

1) Because of the limited registration range of Ne^{20} in cellulose nitrate, only dosimeter #4 in each group (see Fig. 3) could possible have tracks in it that could be recognized as coming from the primary beam. However, dosimeter #4 was on the order of two standard deviations away from the peak of the primary stopping distribution; this implies that the distribution of etch track diameters was weighted heavily towards smaller diameters on this detector. This affects counting efficiency and thus the effective registration range of Ne^{20} in the detector (one cannot see the very small etch pits). In this instance, accurate data could only have been acquired if several sheets of cellulose nitrate had been stacked together, but experimental conditions did not allow this.

2) Because of the extremely high primary fluences (10^7 cm^{-2} to 10^9 cm^{-2}) it was impossible to efficiently count any track density; if the plastic was etched a little too long, the tracks overlapped and became indistinguishable. Even if the cellulose nitrate was etched for the correct amount of time (which was very short), accurate fluence

measurements would still be rather difficult since many of the primary particle etch pits would be very small and hard to distinguish from the background secondary tracks. (It should be noted that the water column setting used was on the order of a mean free path for Ne^{20} in water, so that a large fraction of the beam, at the colony sites, was composed of secondaries.) The high secondary track density on the cellulose nitrate merely compounded the problem.

Prior to exposure, the colonies were incubated at 28°C from 15:00 hours, February 9, to 13:15 hours, February 11, and at 26°C from 14:00 hours, February 11, to 22:45 hours, February 11. The exposures themselves took place between 23:26 hours, February 11, and 00:54 hours, February 12.

DISCUSSION

The main function of our group in these two experiments was to aid Drs. M. Brower and T. Rogers in exposing their biological specimens, as our group has had a great deal of experience in planning and executing various types of exposure schemes at the LBL facility. For the Actinomyces levoris exposures, we could not do any sort of dosimetry with our SSTDs as the registration range of alpha particles in even our most sensitive detector (at that time) is extremely short (a few ten's of microns). We can say, however, that the dose did not vary significantly within each group of cultures.

For the Streptomyces levoris exposures, cellulose nitrate track detectors were included in each exposure to verify that the cultures had been irradiated but because of experimental conditions and the time factor, a more complete dosimetry evaluation was precluded. We did endeavor, however, to establish a fluence calibration but this proved to be impossible to do. From the knowledge of the experimental conditions and our previous experience with a similar beam configuration, we were able to determine a reasonably accurate depth-dose curve.

Table 1. *Actinomyces levoris* 184" Cyclotron Exposure

Exposure	Samples	Dose (rads)
1	C9, C10, C13, C14	280
2	C1, C2, C3, C4	2.8
3	C15, C16, C17, C18	28
4	C5, C6, C7, C8	0.32
5	C19, C20, C21, C22	0.025

Table 2. Streptomyces levoris Bevalac Exposure

Exposure	Sample	Dose* (rads)
1†	A	124.43
	SG	
2†	B	125.86
3	A	126.41
	SH	
4	B	121.39
5	A	600.09
	SA	
6	B	597.45
7	A	617.36
	SB	
8	B	600.05
9	A	1231.42
	SI	
10	B	1273.62
11	A	1287.54
	SJ	
12	B	1333.63
13	A	6088.32
	SC	
14	B	5914.32
15	A	6288.99
	SF	
16	B	6228.58
17	A	12,479.93
	SD	
18	B	12,496.30
19	A	12,412.93
	SE	
20	B	12,451.10

*Entrance doses supplied by the Bio-Med cave operators.

†Each group of five Petri dishes was irradiated once to expose five of the colonies (one in each Petri dish), rotated, and then irradiated once more to expose the other five colonies. Then a new group of five Petri dishes was put in the beam and the procedure repeated.

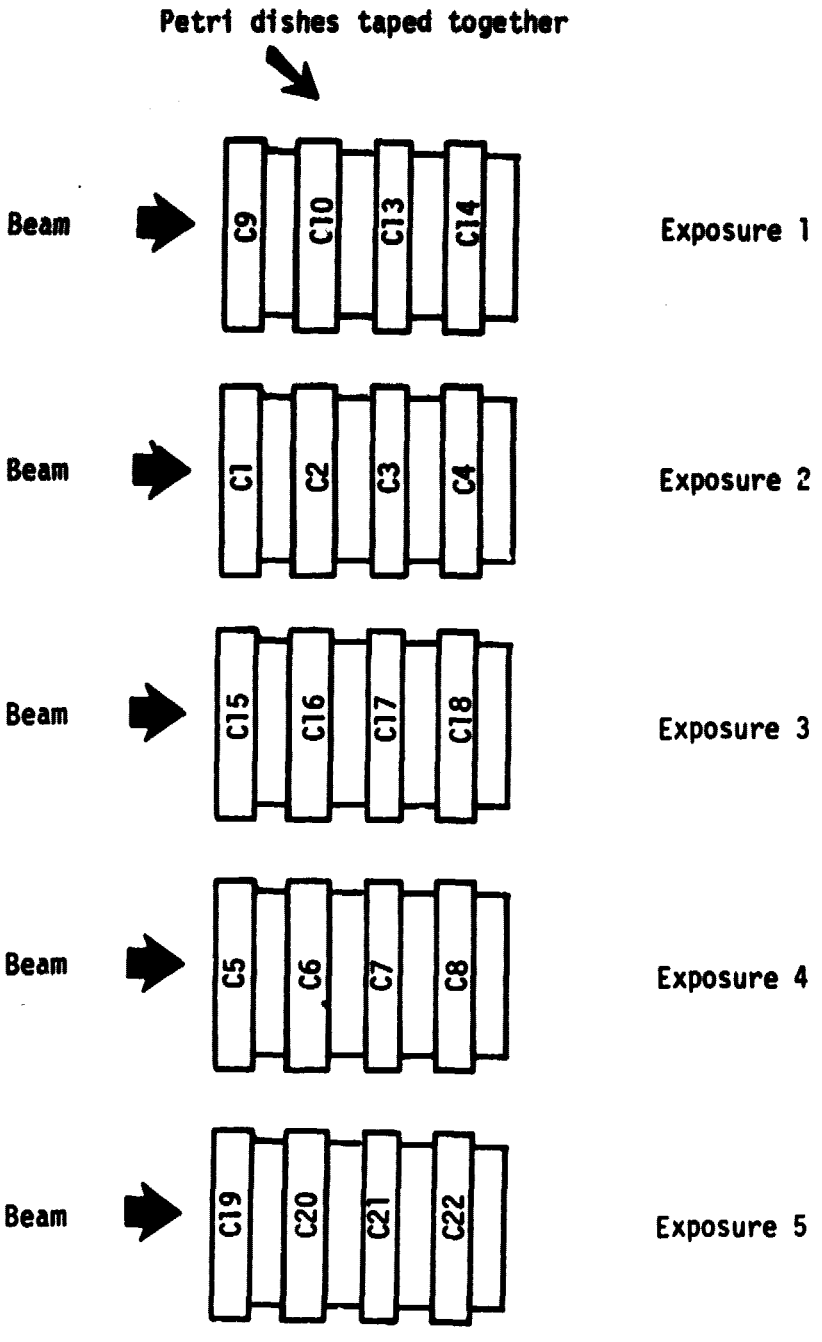


Figure 1. Exposure scheme for Actinomyces levoris at the 184" Cyclotron (233 MeV/nuc alpha particles). Samples 11, 12, 23, and 24 were used as control.

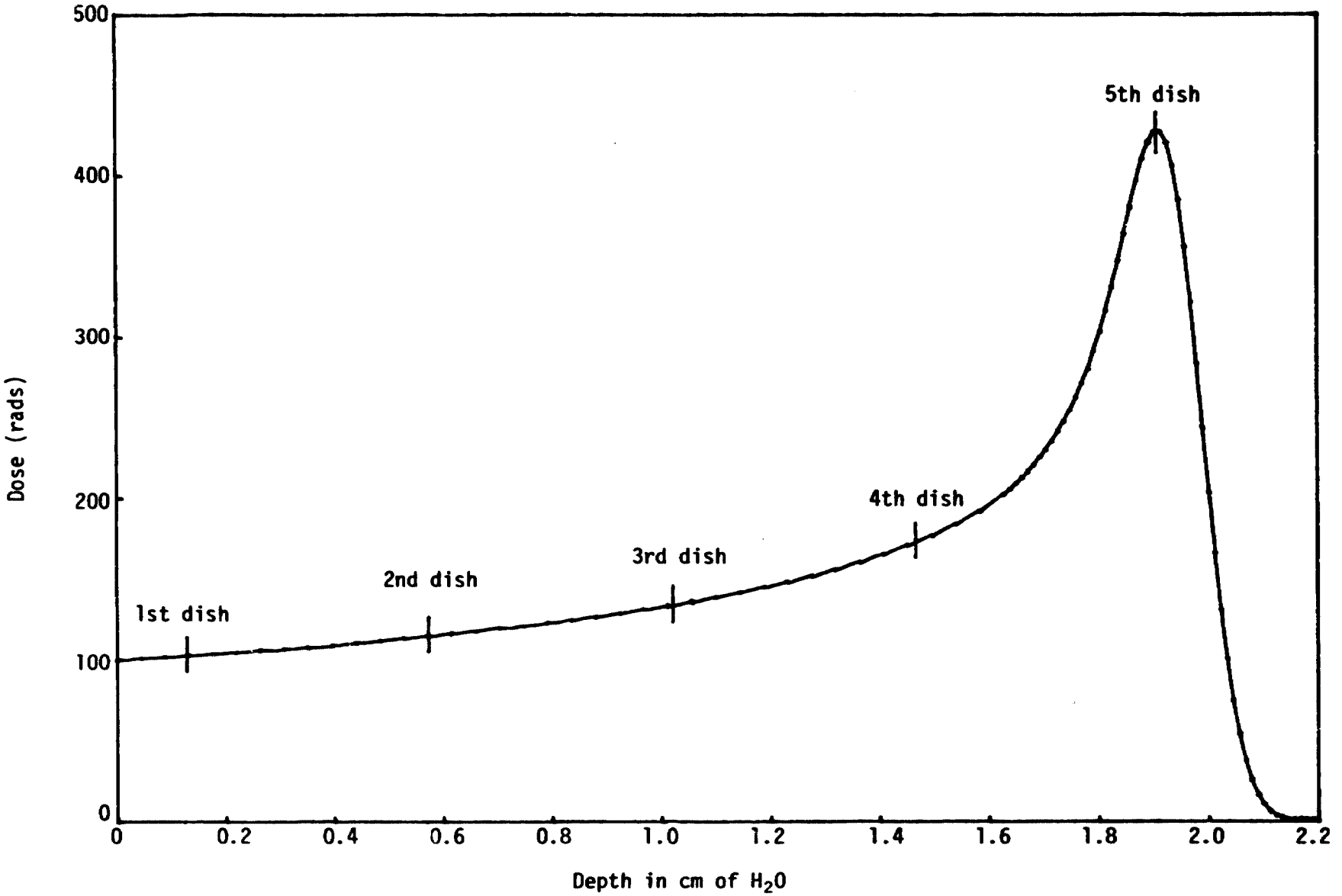
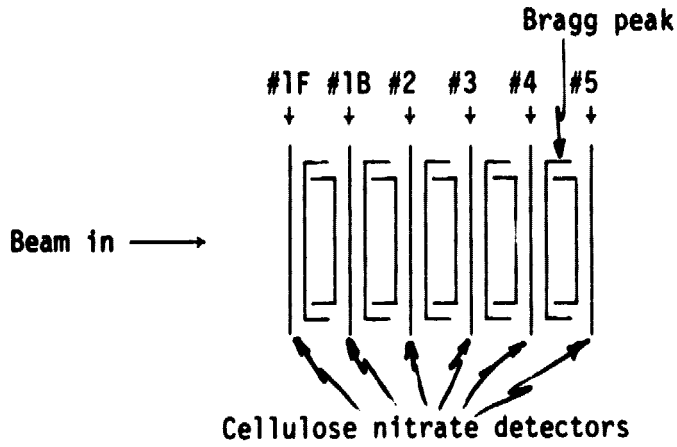
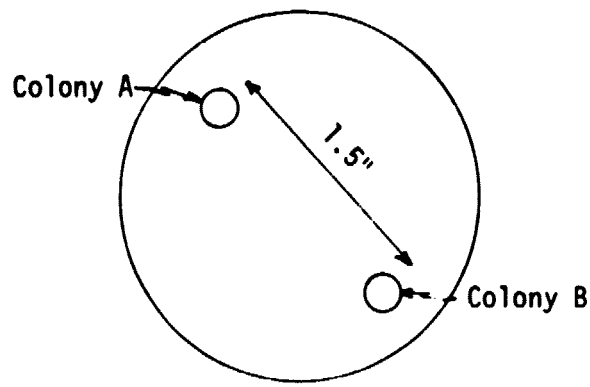


Figure 2. Approximate depth-dose curve for the Streptomyces levoris exposures. The entrance dose has been normalized to 100 rads for ease in scaling. The positions of the colonies are shown according to dish number (the degrading of the beam by the Lexan Petri dishes, culture media, and cellulose nitrate detectors has already been taken care of).



(a)



(b)

Figure 3. a) The arrangement of one Streptomyces levoris exposure unit; the five Lexan Petri dishes and six cellulose nitrate detectors are depicted. The Bragg peak occurs at the colony in the fifth and last dish. b) The positions of each colony in a Lexan Petri dish.